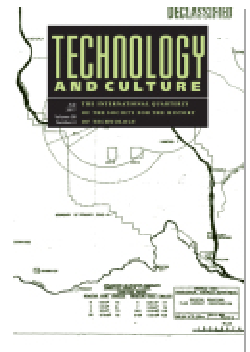
Humans and Machines

Ronald R. Kline



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DA VINCI MEDAL ADDRESS

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First of all, I want to thank Bruce Seely and the members of the committee for selecting me as the recipient of the Leonardo da Vinci medal. I am deeply honored and humbled to receive this award.

When Dave Lucsko informed me of the good news, he reminded me that "typically da Vinci plenaries mix autobiographical reflections with larger historiographical themes of importance to the winner." In a recent presidential address to SHOT, I discussed how several themes in the history of technology were transformed, from the publication of John Staudenmaier's *Technology's Storytellers* in 1985 to the fiftieth-anniversary meeting of SHOT held in 2007.[1] Tonight, I want to focus on how only one theme, the relationship between humans and machines, cuts across my research in that same period.

Interpreted broadly, the theme of humans and machines does not say much, because it covers all of the history of technology. That is especially true if the category "humans" includes organizations as well as individuals, and if "machines" includes all artifacts and embodied techniques. What I want to talk about is more specific. I'll focus on two aspects of the historical relationship between humans and machines: the use of technology; and the attempts to create a science that could explain what it meant to be human in an age of intelligent machines.

When I made the difficult transition from being an engineer to becoming a historian of technology, from the late 1970s to the early 1980s, I had the good fortune to be mentored and encouraged by several teachers and colleagues. I am grateful to Terry Reynolds and Ron Numbers at the University of Wisconsin; and to Ed Layton, Tom Hughes, and Roe Smith in SHOT. At Cornell University, my colleague Trevor Pinch and early graduate students such as Ray Fouché and Suzanne Moon stretched me intellectually in ways I could not have imagined when I started that journey.

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1. Ronald Kline, "Foundational Stories."

A good part of my research has contributed to our profession's criticism of every part of the thesis expressed in the motto of the 1933 Chicago World's Fair, "Science Finds, Industry Applies, Man Conforms."[2] Drawing on the work of Reynolds, Layton, Hughes, and Walter Vincenti, I argued in my book on Charles Steinmetz that his mathematical theories of electrical machines helped create a quasi-autonomous engineering science, which practicing engineers applied, rather than physics, to invent and design electrical power systems at the turn of the twentieth century.[3] In the terms of David Nye, it was a counternarrative, an attempt to combat the dominant cultural narrative, which insists that technology is simply applied science.[4] I chose to write about Steinmetz, the hunchbacked, socialist chief engineer of the General Electric Company in the United States, because I was intrigued by him when I worked as an electrical engineer for GE in the 1970s.

The second half of the book deals with Steinmetz's attempts to professionalize engineering, his socialism, and the creation of a public image that rivaled that of Thomas Edison in the U.S. in the early 1920s. When I worked at GE, I was skeptical enough not to be taken in by the company's attempts to use photos of Steinmetz working in a canoe on a river near his cabin to humanize the corporation. Yet I still wondered why this bastion of capitalism would let a renowned socialist be its chief engineer. In graduate school, I discovered that his politics were a right-wing form of socialism that praised the industrial corporation as the model of a future socialist society. It was an unpleasant discovery for an ex-hippy engineer with long hair, Frye boots, and a red beard to make. But it did help me relate his engineering work inside the company to his attempts outside the firm to reform engineering education and advocate for engineers to be socially responsible.

The Steinmetz book deals only slightly with the theme of humans and machines as I've defined it here. As a committed socialist, Steinmetz believed that engineering would help usher in a utopia in which benign, merit-based corporations such as GE governed society through an industrial senate. Electricity would decentralize politics and clean up the pollution caused by burning coal in cities and homes. It was a political philosophy of technological determinism that set the conditions for the relationship between humans and machines. The electrical systems that his mathematical equations helped make possible would lead to beneficial social and political changes. Steinmetz assumed that ordinary people would use the new tech-

2. Robert W. Rydell, *World of Fair*s, 98–99.

3. Terry Reynolds, *Stronger Than a Hundred Men*; Edwin T. Layton, "Mirror-Image Twins"; Layton, "American Ideologies of Science and Engineering"; Walter Vincenti, *What Engineers Know*; Thomas P. Hughes, *Networks of Power*; Ronald Kline, *Steinmetz*. After completing the book, I turned to the question of how scientists and engineers constructed this relationship through rhetoric. See Kline, "Construing 'Technology' as 'Applied Science.'"

4. David E. Nye, *America as Second Creation*.

nologies of electric light and power systems—emerging on the street and in hotels, factories, and homes—in the manner prescribed by the electrical industry to create a utopia of shorter workdays, more leisure, and longer, more prosperous lives. All society had to do to reach this Eden was to allow industrial corporations to cooperate with each other to build the electrical infrastructure of modernity.

In contrast, my book on technology in rural life took up the theme of humans and machines in earnest.[5] I turned Steinmetz's technological determinism, which I had mildly critiqued, on its head to argue against the gendered "Man Conforms" part of the 1933 world's fair motto. Inspired by the work of Ruth Schwartz Cowan on household technology, Claude Fischer on the telephone, and David Nye on electrification, I shifted my focus from engineers to users. Instead of drawing on my experience as a GE engineer, I drew on my experience growing up in a small town in the rural United States.[6]

I was fortunate enough to document remarkably rich and complex relationships between humans and machines in rural life. I found plenty of archival and published evidence that farm men and women took the new technologies of the telephone, automobile, radio, and electric light and power into their own hands and used them to their own ends in the United States from about 1900 to 1960. In this counternarrative, farm people built their own cooperative telephone systems when AT&T did not serve the countryside, attacked the dangerous "devil wagon" automobile driven into the country by city folk, and then adapted it to do such tasks as shelling corn and washing clothes. They tuned in the country rather than the city on the radio, resisted the Rural Electrification Administration as a New Deal government agency, and selectively purchased electrical appliances. Through these actions, they created their own versions of rural modernity, instead of adopting the urban domestic ideal that manufacturers and the REA worked so hard to convince them to accept.

Theirs was a very close and personal relationship between humans and machines. It was made possible by the rural traditions of independence, making-do, tinkering, visiting, and cooperation that existed on white middle-class farms and farming communities in the U.S., especially before World War II. In my youth, I had seen vestiges of these practices. I had listened to stories about them from my grandfather, who had run threshing machines in the wheat fields of Oklahoma during World War I, and from my grandmother, whom I had seen kill a chicken by wringing its neck with the aid of a rake handle. (That is about as far removed from the urban domestic ideal as I can imagine!) My father, an inveterate tinkerer of farm machinery and Model T's, served as an aircraft mechanic in World War II.

5. Ronald Kline, *Consumers in the Country*.

6. Ruth S. Cowan, *More Work for Mother*; Claude S. Fischer, *America Calling*; David Nye, *Electrifying America*.

When the war ended, the Klines moved from the farm to a very small town to run a hardware store that sold gas and electrical appliances to townsfolk and surrounding farmers in southeastern Kansas. We lived on five acres on the edge of town and kept sheep, calves, and chickens. In the 1950s, we were on a telephone party line, in which all the phones on the line rang at the same time when a call came in. Our phone number was the Morse-code ring of one long and two shorts. You rang that by turning a crank extending from the side of the wooden cabinet of a phone mounted on the wall. Thus, when I found evidence in the archives that American farmers in the early twentieth century were setting up talkfests and playing music for the neighbors on their own party lines, I recognized that they had transformed the rural custom of visiting in person to the newfangled telephone lines. They had co-opted the new medium to continue their rural practices, which were transformed in turn. As tempting as listening-in was to a curious kid like myself, it was taboo in our household!

At the start of this project, Trevor Pinch asked me if I wanted to collaborate with him on a paper on the social construction of the automobile for a conference to be held in Norway. He thought I might have material on Steinmetz's electric car that we could draw upon. Instead, I sent him a photo of a distant family member in Nebraska who had jacked up the rear wheel of a car for his wife to do the wash on the farm in the 1930s.[7] Trevor was intrigued by the extreme interpretive flexibility of the car depicted in the photo, and we started working on the paper "Users as Agents of Technological Change," which *Technology and Culture* published twenty years ago this year. I wanted to stretch the social construction of technology (SCOT) approach to cover such power relations as gender structure and identity. I think Trevor wanted to do some more colonizing for his and Wiebe Bijker's brand of social constructivism.[8]

We worked well together, meeting weekly in my quiet engineering office to sort out the division of labor for research, analysis, and writing. The only major point on which we disagreed had to do with the theme of humans and machines. Trevor wanted to discuss only those interpretations of the car that led to changes in an artifact. For example, using the car to plow the fields prompted companies to bring out tractor kits for autos, and using the car to do the wash prompted manufacturers to add a power-takeoff option to tractors. Trevor wanted to focus on the theme of users as agents of technological change in order to retain the sharp analytical edge of SCOT. I wanted to talk about all social interpretations of the rural car, uses that led to technological changes and those that did not, such as farm women using the car to run their egg business and expand their traditional gender roles. In the terms of philosopher Isaiah Berlin, it was a classic clash

7. I discovered after the book was published that I had erroneously identified the farmer in the photograph as being from Kansas and the woman as being his daughter.

8. Trevor J. Pinch and Wiebe Bijker, "The Social Construction of Facts and Artefacts."

between the hedgehog who saw the world through one grand idea and the fox who wanted to explore many things.[9]

We settled this friendliest of disputes by focusing on innovative users for the paper in *Technology and Culture*, which led to much good work in the sociology and history of innovative users. I added the broader uses to the chapter on the car in *Consumers in the Country* as an example of the mutual construction of technology and social change. If you read the *T&C* piece and the chapter together, you get a clear sense, I think, of David Edgerton's criticism of SCOT for focusing on technological innovation even when it deals with users.[10]

Let me turn now to the history of cybernetics and information theory in the United States. These new post–World War II sciences grappled with the question of what it meant to be human in the emerging age of electronic computers. When I began to speak on this research about a decade ago, I found that the information theory of Claude Shannon would put audiences to sleep, whereas the cybernetics of Norbert Wiener would wake them up and lead to lots of questions. As a former engineer who had worked on the computer control systems that could launch nuclear missiles from submarines—which gave me an occupational deferment during the Vietnam War—I could not understand why cybernetics, which drew on control engineering, was so cool in the twenty-first century. I thought the digital age owed a greater debt to information theory. Fred Turner's wonderful book on the countercultural origins of cyberculture helped clear up that mystery. Fred shows that American artists, musicians, and readers of Stewart Brand's *Whole Earth Catalog* viewed cybernetics as a means to liberate them from the technocracy of Big Brother computer systems. This digital utopianism grew out of what Turner calls the "forgotten openness of the Closed World."[11]

Yet I knew from my previous life as a computer engineer and from my current one at Cornell, where one of my offices is down the hall from faculty in control engineering and information theory, that there was more to the story. I recalled that GE engineers had interpreted communication and control systems—the basis of cybernetics—in a closed Cold War fashion. Furthermore, my engineering colleagues at Cornell informed me that cybernetics still had a flaky scientific reputation in the United States, precisely because of its association with the counterculture. Why are you so interested in Norbert Wiener? they asked; Claude Shannon is the important figure! But to me, Shannon was boring and Wiener was exciting. So I studied the cybernetics craze in the U.S. in the 1950s. I found that there was also a great deal of intellectual excitement about information theory at the time, even when it wasn't tied to cybernetics. Shannon wasn't so boring

9. Isaiah Berlin, *The Hedgehog and the Fox*.
10. David Edgerton. "Innovation, Technology, or History."
11. Fred Turner, *From Counterculture to Cyberculture*.

after all, even though he had tried to tamp down that enthusiasm in a famous editorial called "The Bandwagon." My engineering colleagues praised it to me fifty years later in a not-so-subtle form of what sociologists of science call boundary work.[12]

The theme of humans and machines was not on my radar at this time, even though I had taught Donna Haraway's "Cyborg Manifesto" in the 1990s.[13] That changed in the first decade of this century, when I began teaching science fiction novels in my undergraduate classes and helped supervise Heidi Voskuhl's excellent PhD dissertation on automata in eighteenth-century Europe.[14] In graduate seminars, I began to come to grips with literary theorist N. Katherine Hayles's provocative 1999 book on cybernetics and the posthuman. The book deals with the disembodiment of information, the creation of the cyborg as a "*technological artifact and a cultural icon*," and "how a historically specific construction called *the human is giving way to a different construction called the posthuman*." By "posthuman," Hayles refers to the loss of human subjectivity characteristic of the European Enlightenment, not a reconstruction of the body through cyborg engineering.[15]

Although I criticized Hayles's presentist history of cybernetics and her treatment of Wiener and Shannon, her book impressed upon me the importance of the theme of humans and machines to cybernetics. I kept that in mind while writing my book on cybernetics.[16] I tried to explain why so many scientists, engineers, and humanists in the U.S. in the 1950s and 1960s thought cybernetics could shed new light on the age-old question about the relationship between humans and machines. For them, the basis of cybernetics was a powerful analogy: that the principles of information-feedback machines, which explained how a thermostat controlled a household furnace, for example, could also explain how all living things—from the level of the cell to that of society—behaved as they interacted with their environment.

Central to their quest was cybernetic modeling. Human brains were modeled as electronic digital computers by neuroscientist Warren McCulloch and mathematician Walter Pitts, who equated neural nets to a Turing machine. In turn, digital computers were modeled as human brains when mathematician John von Neumann used the theory of McCulloch and Pitts to describe what came to be known as the von Neumann computer architecture, the hallmark of digital computing.

In the human sciences, researchers in the U.S. used cybernetics and information theory to model humans as machines in regard to behavior.

12. Claude E. Shannon, "The Bandwagon"; Thomas F. Gieryn, "Boundaries of Science."

13. Donna J. Haraway, "A Manifesto for Cyborgs."

14. Which forms the basis for Adelheid Voskuhl, *Androids in the Enlightenment*.

15. N. Katherine Hayles, *How We Became Posthuman*, 2 (her emphasis).

16. Ronald R. Kline, *The Cybernetics Moment*.

Such notable figures as cognitive psychologist George Miller and linguist Roman Jakobson employed an "information calculus" to model human judgments and the structure of language. Herbert Simon, Karl Deutsch, and other prominent social scientists employed feedback circuits to model human decision-making and social interactions in management science, political science, and psychology. In the 1970s, anthropologist Gregory Bateson, husband of the more famous anthropologist Margaret Mead, became a guru to the ecological wing of the counterculture when he created a radical epistemology of cybernetics. In Bateson's holistic concept, the computer was a small part of an information-feedback circuit that extended from the human organism to its environment and back again, forming an immanent mind. That epistemology led to the current movement known as second-order cybernetics.[17]

Researchers in the physical sciences and engineering in the U.S. used cybernetics to model machines as human. They created new artifacts in the areas of bionics, artificial intelligence, and cyborgs. Several cyberneticians and information theorists were involved in this effort. Claude Shannon helped organize the 1956 conference on Artificial Intelligence, which gave the field its name. Warren McCulloch at MIT and Heinz von Foerster at the University of Illinois created artificial neural networks in AI. They also helped establish the new military-funded field of bionics, which looked to the evolutionary design of living systems for clues about how to design more reliable electronic systems. In the same period, researchers fused humans with machines to create cyborgs (cybernetic organisms). The term was coined by researchers in space medicine in 1960, who proposed embedding cybernetic systems such as an artificial heart and the feedback monitoring of antiradiation drugs in the bodies of astronauts to enable them to explore outer space without clumsy spacesuits! Fortunately, NASA's Cyborg Project did not get off the ground. Since then, the word *cyborg* has come to denote a wide range of human-machine constellations, from the heart patient with a pacemaker, to enemy cyborgs on *Star Trek*, to Donna Haraway's concept of an ironic political myth that can break down dualisms of race and gender.

In 1950 Norbert Wiener wrote a popular book on the social implications of cybernetics that covers all these issues and is still in print today. In *The Human Use of Human Beings*, Wiener warned of the unemployment and other social ills that would result from the misapplication of cybernetics by authoritarian governments in regard to automatic factories and secrecy in military-funded research. Yet he also thought cybernetics would strengthen liberal democracy if it was applied to language, law, education, and government. Passages such as the thought experiment of transmitting a human over a telegraph line by sending the information needed to reconstruct the human at the other end continues to fascinate today's students. So

17. See, e.g., Stuart A. Umpleby, "Second-Order Cybernetics."

does the idea of the computer as a communication machine, not as the smart terminal of a communications network, but as a stand-alone machine that forms an information feedback loop with its user.[18] After all these years, *The Human Use of Human Beings* is still a good book to think with.

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I argue that when the cybernetics moment ended in the U.S. in the 1970s—as cybernetics and information theory lost their status as universal sciences—this rich way of talking about humans and information machines also ended. It was replaced by an impoverished discourse of information as commodified data and "cyber" as an all-purpose, nearly meaningless adjective. One can see the beginnings of this change in Stewart Brand's remarkable booklet, *II Cybernetic Frontiers*. Published in 1974, it contains two articles, one on the frontier of organic cybernetics (Bateson's epistemology), the second on the frontier of machine cybernetics (research done at the Stanford AI lab and the XEROX Palo Alto Research Center). Although Brand predicted correctly that machine cybernetics would make computers accessible—which it did through the PC and the Internet—he gave it second billing behind organic cybernetics. "What Bateson was getting at," Brand claimed, "will, *indirectly*, inform damn near everybody's lives."[19]

Bateson stretches the theme of humans and machines to its limit. It is far beyond Steinmetz's technological determinism, the efforts of farm people to adapt urban technology to rural life, and first-order cybernetics. For him, cybernetics was not merely a means to model humans as machines. Nor was he interested in the creation of humanlike robots, nor the fusing of humans with machines into cyborgs—the sites of so much of today's work in machine cybernetics. Batseon was after bigger game: a theory of mind immanent in feedback loops connecting humans with their environment. Like Stewart Brand, Bateson believed that organic cybernetics could help solve the environmental crisis of the 1970s by showing the unity of mind and nature. That is a far cry from the goal of designing a better human-computer interface based on user studies.

Let me conclude with a story about the hospitality of SHOT. I experienced this when I attended my first meeting in Toronto, in 1980, and gave a paper in a dissertation-in-progress session, chaired by Roe Smith. In the Q&A period, an old gentleman with white hair stood up and said in a cranky, authoritative voice, "Unless I've forgotten everything I ever knew about electrical engineering, Steinmetz did invent the method of solving differential equations by complex-quantities." I replied that I was not surprised that he held this view, because textbooks had stated it as a matter of fact since the turn of the century. My research showed, however, that the method was invented simultaneously by several engineers, including Stein-

18. Norbert Wiener, *The Human Use of Human Beings*. The second, revised edition, published in 1954, is in print.

19. Stewart Brand, ed., *II Cybernetic Frontiers*, 7 (his emphasis).

metz. It came to be called "Steinmetz's method" because he popularized it in numerous articles and books.[20] The old gentleman sat down in a huff.

I later learned that he was John Brainerd—a past president of SHOT who had headed the pioneering ENIAC computer project at the University of Pennsylvania during World War II.[21] After the session ended, Roe Smith and others told me that I had handled Brainerd's question well. They made me feel welcome, that I was no longer an engineer, that I was part of an exciting intellectual enterprise of writing the history of technology, even if it meant challenging the account of a famous historical actor.

I am happy to say that during my thirty years of teaching at Cornell, many of my graduate students have told me about feeling welcome in SHOT. It pleases me to no end to watch the more senior scholars among them extend support and encouragement to graduate students who have found their way into our field—and who will transform it in the process.

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20. The paper focused on how GE publicized Steinmetz to combat antitrust charges, not the simultaneous invention of Steinmetz's method, which I had mentioned in the introduction.

21. For his SHOT presidential address, presented in October 1975, see John G. Brainerd, "Genesis of the ENIAC."

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